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Suppression of mountain pine beetle infestations in lodgepole pine forests

L.H. McMullen, L. Safranyik & D.A. Linton

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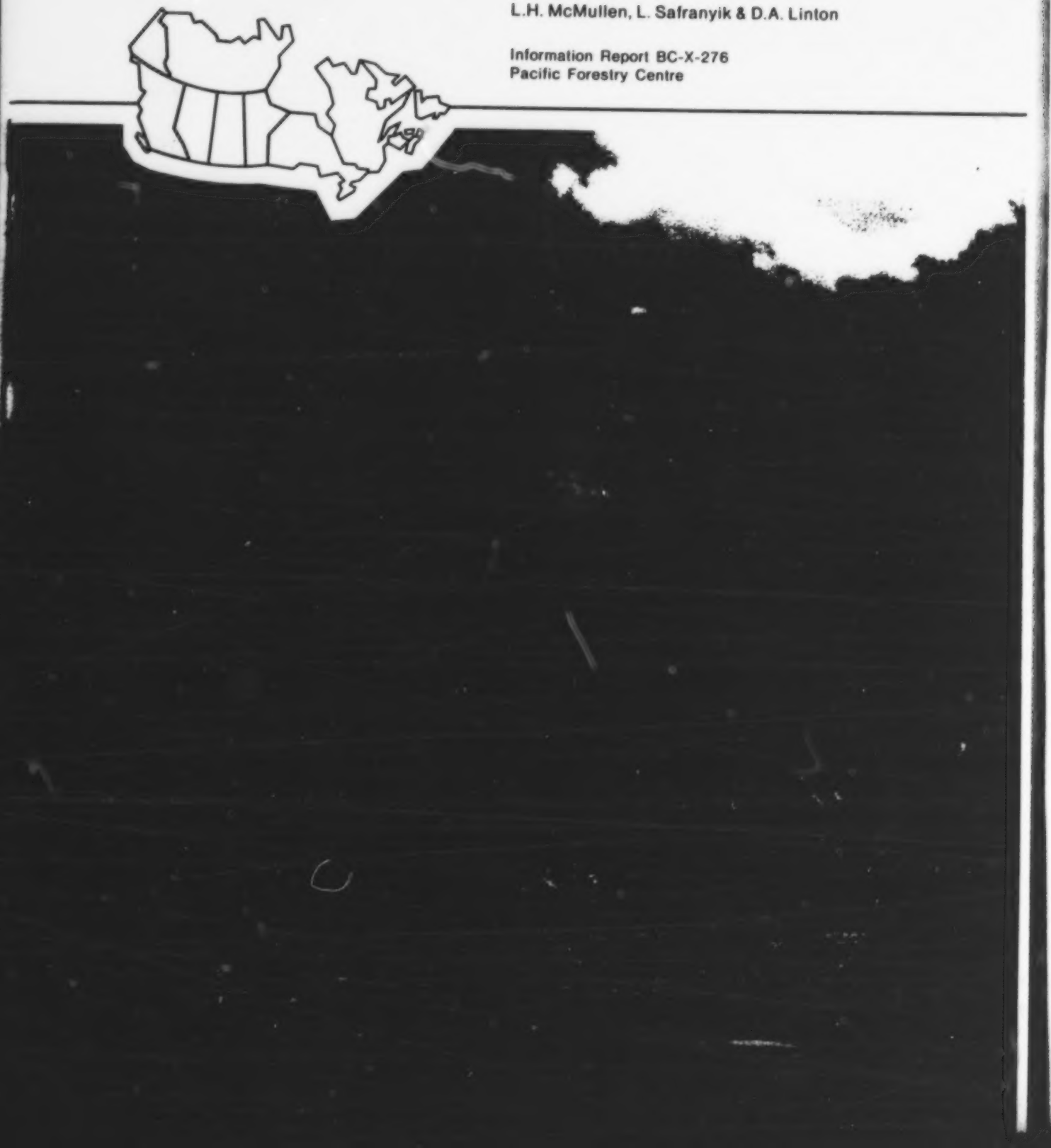

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Preface

Management of lodgepole pine to reduce mountain pine beetle damage has been described, and direct control addressed in general terms (Safranyik *et al.* 1974) and Safranyik (1982) summarized the principles of direct control, listing the commonly used methods. These methods are described in several publications, many of which are not known or available to pest management personnel. This brochure, therefore, is addressed to pest management personnel in the forest industry and government who are involved in management of mountain pine beetle populations in western Canada. It describes the philosophy and procedures of direct control of the mountain pine beetle in lodgepole pine stands. Published information is augmented by unpublished results of experiments performed by the authors in the Cariboo Forest Region during the past 10 years and by their collective judgment where information was lacking. We sincerely acknowledge the support of the Protection Division of the B.C. Ministry of Forests.

Preface

Safranyik et coll. (1974) ont décrit des méthodes d'aménagement du pin tordu qui permettent de réduire les dégâts causés par le dendroctone du pin ponderosa et ils ont traité, en termes généraux, de la lutte directe contre cet insecte. Safranyik (1982) a résumé les principes de la lutte directe en en énumérant les méthodes les plus usitées. Diverses publications décrivent ces méthodes dont plusieurs sont inaccessibles ou demeurent inconnues chez le personnel chargé de la lutte. La présente publication s'adresse donc tout particulièrement à ceux qui, tant dans l'industrie forestière que dans l'administration, contribuent à la répression du dendroctone dans l'Ouest canadien. Elle décrit la doctrine et les méthodes de lutte directe dans les peuplements de pin tordu. Elle ajoute aux données publiées les résultats inédits d'expériences réalisées par les auteurs dans la région forestière du district de Cariboo au cours des 10 dernières années et le fruit de leur appréciation collective quand l'information fait défaut. Les auteurs remercient sincèrement la Division de la protection du ministère des Forêts de la Colombie-Britannique pour l'appui qu'elle leur a accordé.

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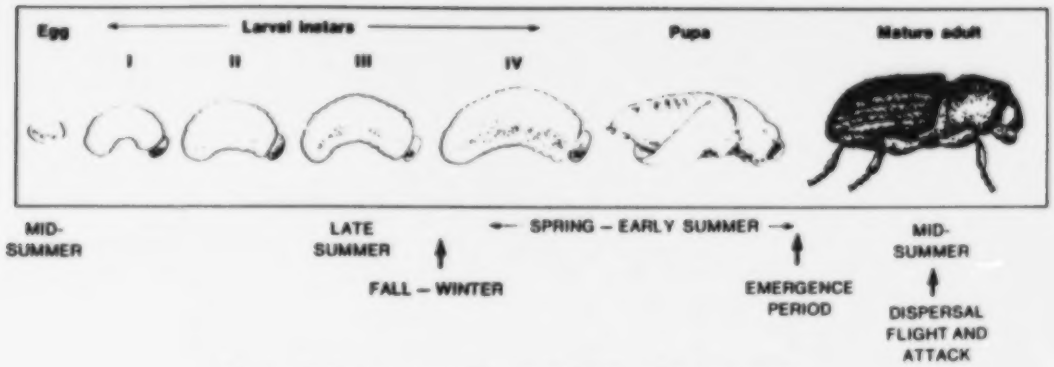


Fig. 1. Typical one-year life cycle of the mountain pine beetle.

Introduction

Mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopk. (Coleoptera: Scolytidae), is the most destructive insect pest of mature pines in western Canada (Safranyik *et al.* 1974). In recent years, the loss caused by this beetle in pine stands (particularly lodgepole pine, *Pinus contorta* var. *latifolia* Dougl.) has been devastating; losses in British Columbia from the 1983 attack amounted to 41 million trees killed over an infested area of 482 000 hectares (Wood *et al.* 1985).

Mountain pine beetle typically has a one-year life cycle in British Columbia. Peak emergence, flight, and attack by young adults on new host trees occurs in mid to late July, but may continue until September. Eggs are laid in the phloem and larvae overwinter and complete development the following year. The life cycle and life stages of MPB are illustrated in Figures 1 and 2. The most common deviation from the one-year life cycle is a partial or complete two-year cycle, particularly at high elevations and near the northern edges of the beetle's distributional range. Changes in the life cycle may result in major shifts in the temporal distribution of the various brood stages and damage symptoms, including foliage discoloration which usually starts in late May and early June of the year following attack.

Reduction of losses to mountain pine beetle is based on two general approaches: long-term stand management and direct control. Ideally, control lies in long-term stand management aimed at reducing stand susceptibility to MPB (Safranyik *et al.* 1974). However, extensive susceptible stands and infestations are present today and, despite the best efforts of intensive management, some future infestations will require direct procedures. Long-term management will require changes in silvicultural and harvesting practises, as well as the capability of direct control.

Background

What is direct control?

The objective of direct control is to reduce beetle numbers to levels that do not cause economically important damage, or to reduce the rate of population expansion in order to implement a longer-term solution. For example, direct control might be used to reduce the spread of an infestation while access is being developed for harvesting. For the purposes of direct control, infestations can be viewed in much the same manner as fires. The most practical and economically practicable approach is to extinguish the fire when it is small. Similarly, direct control of MPB is most feasible when infestations are small.

Sanitation logging, in which infested trees containing living beetles are removed from the stand and utilized (thereby killing the beetles), is the

Fig. 2. Life stages of mountain pine beetle: a) adult beetles in egg galleries. b) eggs. c) late stage larva. d) pupae. e) teneral adults in pupal cells. f) emergence holes. g) mature adult (From Safranyik *et al.* 1974).

5 mm
c
5 mm
d

Fig. 3. Incipient infestations of mountain pine beetle in lodgepole pine.

most commonly used and frequently the most efficient method of direct control of MPB in B.C. As sanitation logging is generally not suitable for treating small, scattered infestations or infestations in remote areas, suppression techniques based on treatment of individual trees are an important part of direct control.

Small groups of infested trees scattered in a stand, or adjacent to areas that have been logged for beetle control, are usually considered as incipient infestations (Fig. 3). Characteristically, these incipient infestations are smaller than 2 ha and there is generally a yearly increase in the number of trees per spot and the number of infested spots. Eventually, in the epidemic phase, the infested spots coalesce into one or several large infestations.

In susceptible stands, mountain pine beetle will continue to be a threat after control of incipient infestations. Therefore, direct control of incipient infestations must be viewed as a delaying tactic until a) long-term management plans can be implemented, or b) damage caused by the insect is reduced to acceptable levels. If repeated application of direct control does not bring about the desired delaying effect, the manager must be prepared to harvest or convert the stand to a less susceptible condition.

Requirements for effective direct control

Direct control is expensive in time, effort, and resources and, in spite of its long history, there is no general agreement among scientists and foresters regarding its effectiveness in reducing losses. Recent theoretical work (Berryman 1978) and field experiments (Whitney *et al.* 1978) indicate that direct control can be a sound strategy and that tactics can be developed to implement it. Experience suggests that, in order to be effective, suppression work should be based on the following principles:

(1) The initial treatment over the entire area to be protected must be completed within one or two seasons. It is desirable that the control area be isolated as far as possible from other sources of infestation. Otherwise, annual recleaning of the control area may be necessary as long as infestations prevail in surrounding

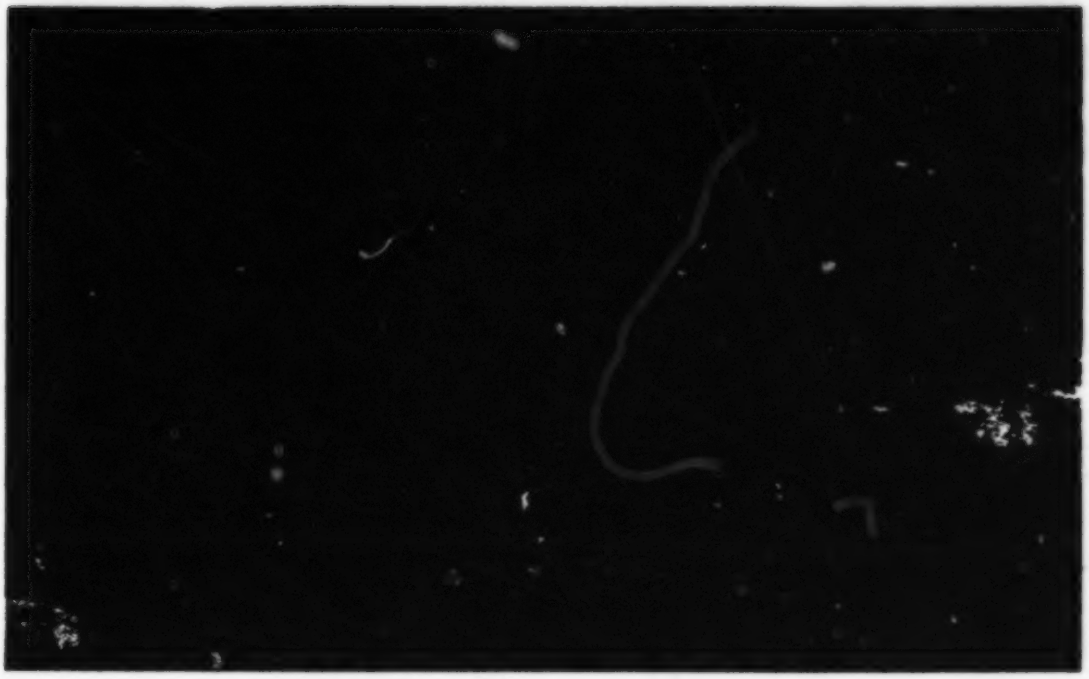


Fig. 4. Salvage logging a severely infested stand.

areas. When the infested areas cannot be treated within the specified time period, it is generally better to salvage the stands (Fig. 4) because direct control is not likely to be successful. This is partly because during epidemics there is usually a 2-fold to 5-fold annual increase in the number of infested trees. Therefore, the increase in numbers of infested trees will be greater than could be treated in any year. The spread of infestations and the inefficiency in finding infested trees are additional complicating factors.

(2) Control work must continue as long as there is evidence of beetle activity as indicated by yearly stand surveillance.

(3) All relevant tactics must be applied in a coordinated manner when possible. No technique should be considered in isolation or applied in all circumstances.

(4) Success in direct control is dependent upon the thoroughness in all aspects of treatment application and of surveillance. The object is to treat every infested tree in the control area.

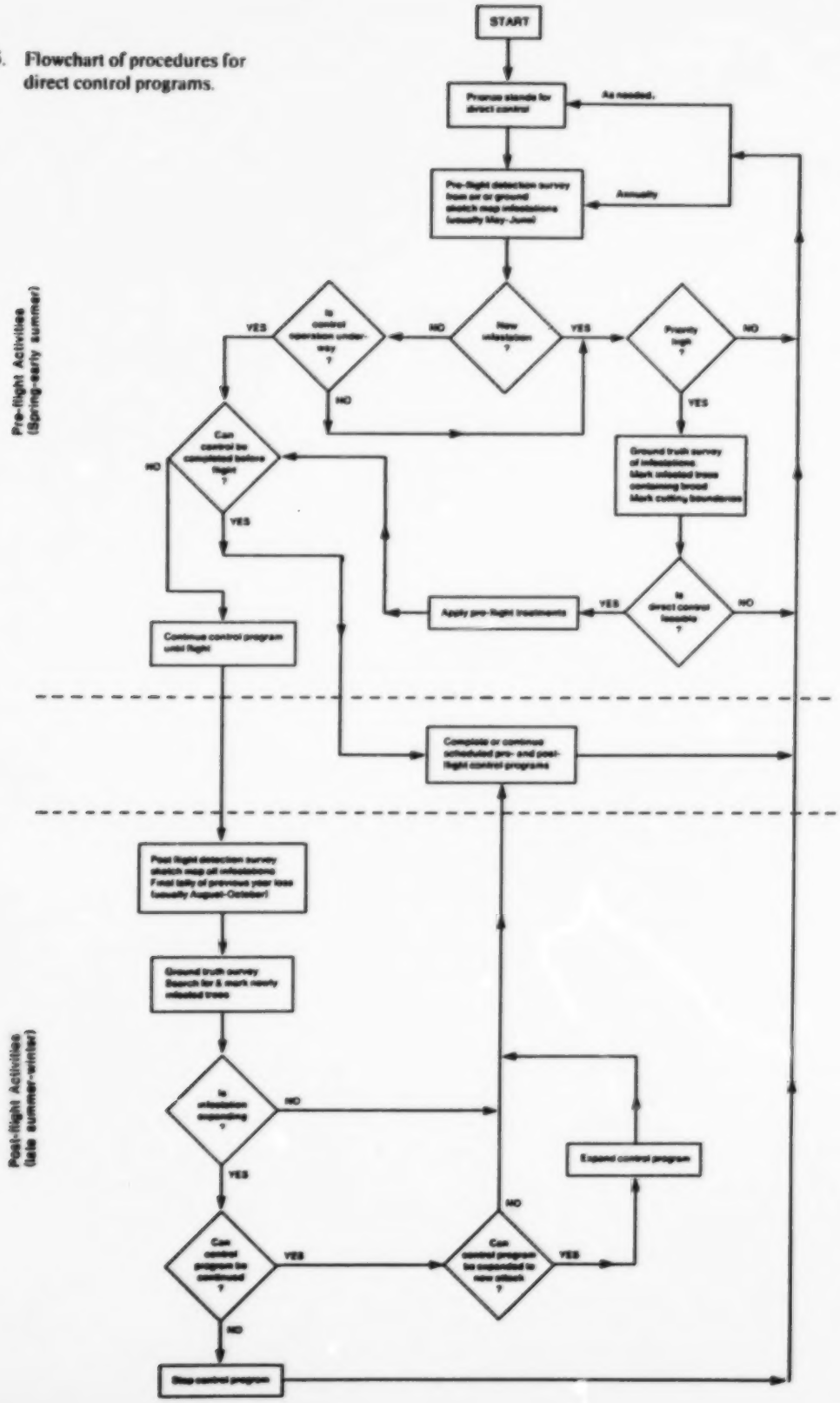
Procedures of direct control

Major steps in direct control are (1) priorization of stands for treatment, (2) annual surveillance and detection and delineation of areas where control may be feasible with available resources, and (3) reduction of beetle numbers. The flow chart in Figure 5 depicts the main steps and procedures of direct control operations. These operations are grouped into pre- and post- beetle flight activities. Within each activity, the sequence and methods of surveys and treatments, and decisions regarding treatment priority and practicability of control, are identified. The main purpose in developing the flow diagram was to show the integration of the various operational procedures in the context of a year-round direct control program.

Priorization of stands

Since treatment of infested trees is expensive, it is usually not possible to treat all infestations. Therefore, stands of lodgepole pine should be priorized according to their socioeconomic value

Fig. 5. Flowchart of procedures for direct control programs.



and risk of loss from MPB infestations.

The socioeconomic values of a stand, which should include all major timber and non-timber resources and related short-term and long-term benefits, are best determined at the regional level by the agencies responsible for the management of these resources. These values can be expressed in relative terms as low, medium and high, and combined with stand hazard rating (Table 1) to give a stand priority rating such as Table 2. The stand hazard rating system proposed by Hall (1985) combines the climatic hazard map of Safranyik *et al.* (1974) (Fig. 6) with elevation, stand and site characteristics (Amman *et al.* 1977; Safranyik 1982) into a comprehensive system for rating lodgepole pine stands. Ratings of socioeconomic values and stand hazard can be combined many ways to priorize stands for treatment. Table 2 represents a reasonable approach and gives equal weighting to socio-economic values and stand hazard.

Control action should be concentrated in stands having the highest management priorities, and in nearby stands if the beetle is threatening from these. The locations, numbers and sizes of infestations selected for control action will depend, to a large extent, on the resources available to the manager.

Table 1. B.C. Ministry of Forests Stand Hazard Rating System (Hall 1985)

Factor	[Value =	Hazard Level Low (1)	 Moderate (2)	 High (3)]
Climatic hazard zones (Fig. 16)		Very low	low, moderate	high, extreme
Elevation within P1 zone		high	mid	low
Average dbh (P1) (cm)		<17	17-20	>20
Average age (P1)		<60	60-80	>80
Site		poor	medium	good

Step 1 Determine climatic hazard zone of stand from Fig. 16.

Step 2 Assign numerical ratings for each of the five factors for each stand as given above.

Step 3 Sum the assigned values for each of the five factors for each stand to obtain a Total Hazard Value.

Step 4 Assign a Stand Hazard Rating on the basis of the following ranges of Total Hazard Value:

Total Hazard Value	Stand Hazard Rating
5 - 7	Low
8 - 12	Moderate
13 - 15	High

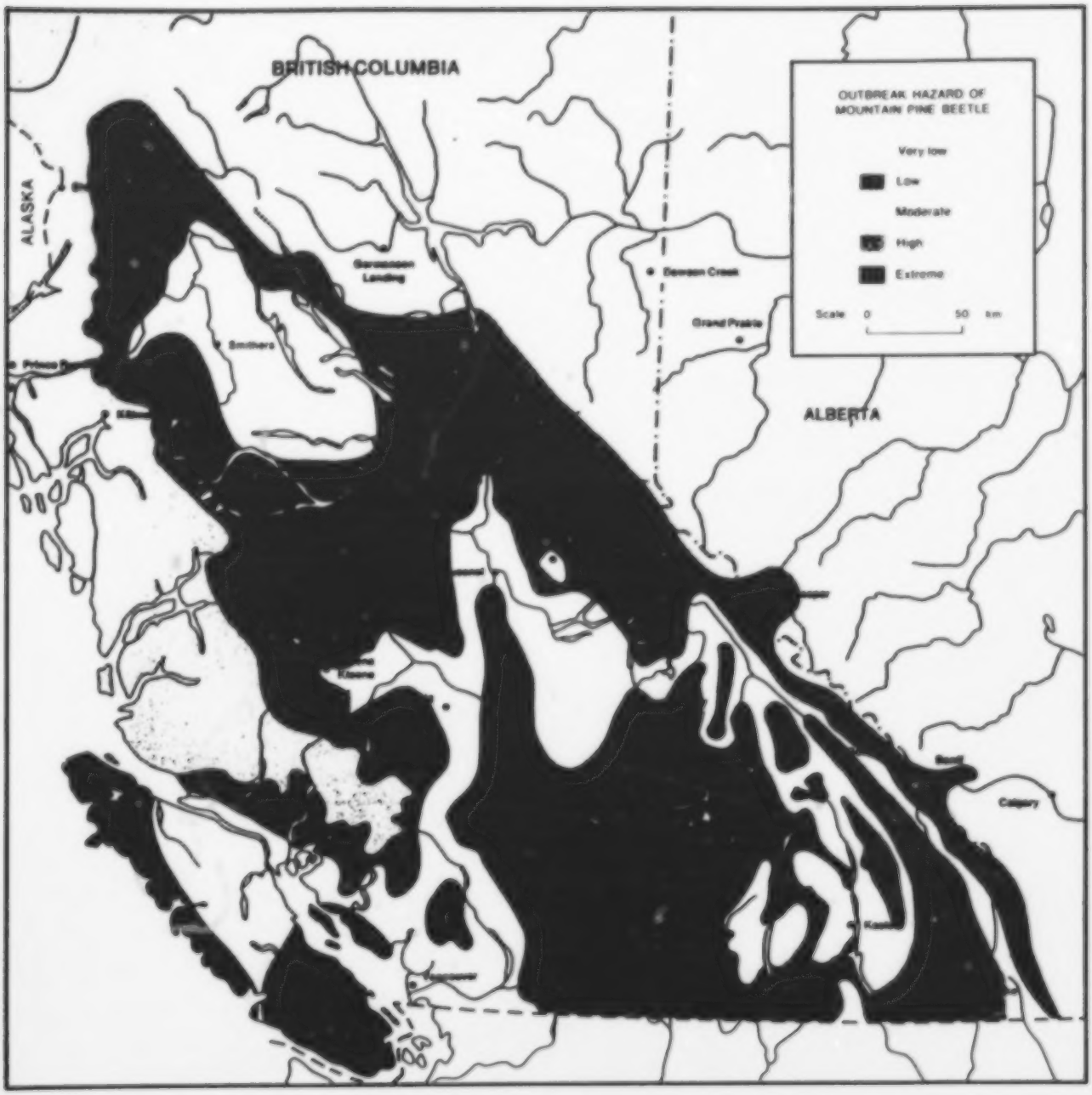


Fig. 6. Climatic hazard map for mountain pine beetle in B.C. (From Safranyik *et al.* 1974)

Table 2. Priority rating of stands for treatment

Stand hazard rating	Socioeconomic value of stand		
	Low	Medium	High
Low	Very low	Low	Medium
Moderate	Low	Medium	High
High	Medium	High	Very high

Annual surveillance and detection

Detection programs combine aerial and ground-based procedures and are done annually to locate infested trees and to monitor past control operations for possible reinfestation. The pre-beetle flight detection program should be done by aerial surveillance during May-June, when the foliage of most of the trees attacked the previous year will have faded to straw color (Fig. 7). The infested trees must be marked in such a manner as to allow ground crews to reach them. Scattered, infested trees are difficult to find in a stand, even with a good map or aerial photo. A trail of paper released from an aircraft, from the infested trees to a well-defined landmark, is a useful method of locating infested trees. The groups of trees with discolored (yellow and red) crowns as well as adjacent green trees should be examined on the ground for the characteristic external evidence of infestation described in Safranyik *et al.* (1974) and all infested trees should be marked for treatment. Older dead trees with red foliage can also be marked for felling to prevent confusion in subsequent surveys.

As the foliage of infested trees usually begins to fade during mid-spring and the adult beetles fly to attack new trees in mid-summer, detection procedures based on foliage discoloration of infested trees allow little time for control work before beetle flight. The only method of locating infested trees before foliage discoloration occurs is ground examination of the lower boles of trees in the vicinity of old infestations for the presence of boring dust, pitch tubes, and under-bark evidences of infestation (Fig. 8). In localized infestations, such as along the margins of logged areas, ground examination is practical. In scattered infestations over large areas, a portion of the green-infested trees can be concentrated in predetermined areas through the use of pheromone-baited trap trees, as described later. The remainder of the infested trees must be located and treated after foliage discoloration.

The use of pheromones for detecting the presence of mountain pine beetles and for monitoring population changes is neither necessary nor practical. The MPB is found in low numbers in most mature pine stands. Population changes can be monitored more efficiently and effectively using aerial reconnaissance combined with ground checking to annually record the numbers of infested trees.

Reduction of beetle populations

There are two major approaches to reducing beetle populations:

(A) treatment of infested trees to kill beetles and their broods under the bark;

(B) preflight baiting of uninfested trees to trap flying beetles.

Although trapping of the beetles in baited trees does not reduce the beetle population by itself, it may make the control work using the various

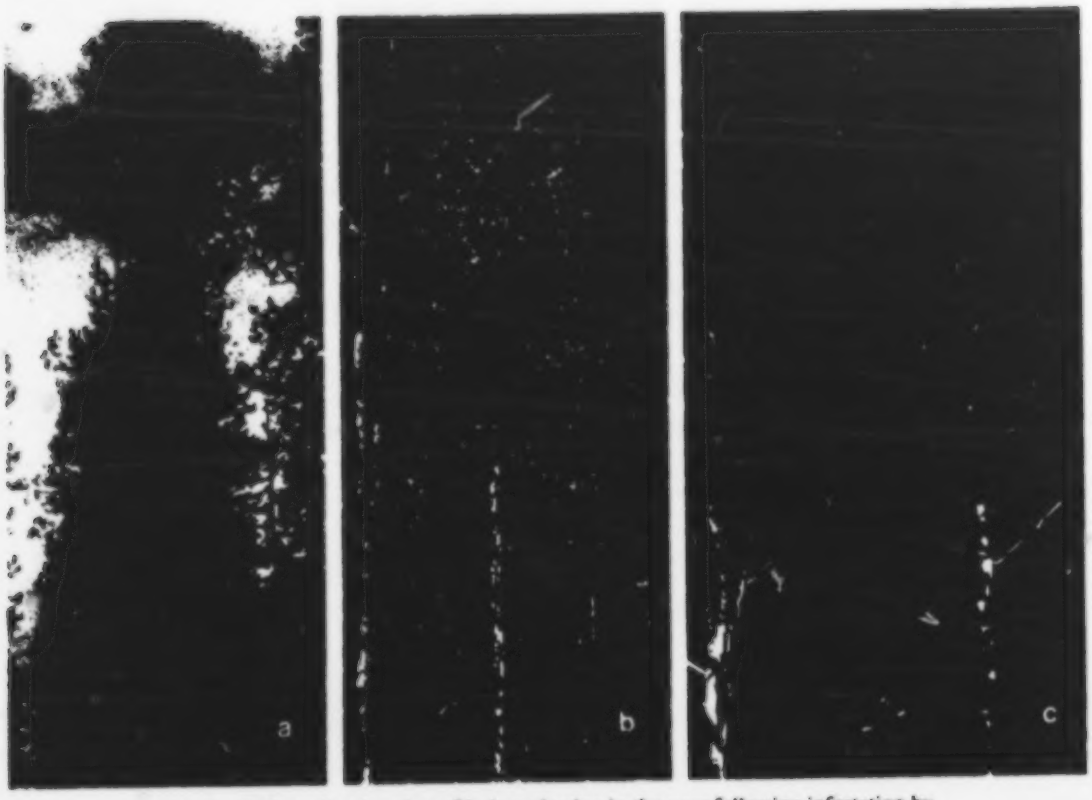


Fig. 7. Foliage discoloration of lodgepole pine in the year following infestation by mountain pine beetle: a) slight fading by May or June. b) light yellow color by June or July. c) red brown color by July or August. (From Safranyik *et al.* 1974)

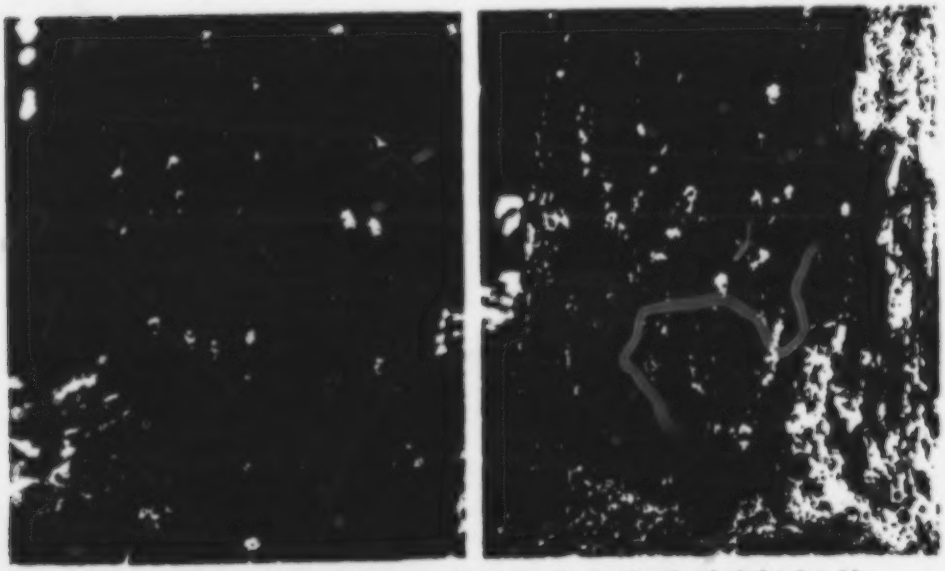


Fig. 8. Bole symptoms of infestation by mountain pine beetle. a) pitch tubes. b) boring dust around base of tree.

Fig. 9. Sanitation logging.

treatment options more efficient. Also, application of some treatments, such as the use of pesticides to kill attacking beetles, is feasible only when used in combination with baited trees. Hence, these approaches should be combined on each control operation. The following provides a description of the procedures, and their advantages and disadvantages:

A) Treatment of infested trees to kill beetles under the bark

The following treatments are all effective when carried out carefully and thoroughly. Each treatment has its advantages and disadvantages related to the ease and the timing of application. Different treatments can be used sequentially and in combination throughout the life of the insect under the bark.

(1) Sanitation logging (Fig. 9)

This method can be effective in reducing beetle populations but its practicality is limited by access, infestation size, ownership, consideration of other forest values, and timber markets. Another consideration is the speed with which cutting permits can be issued so that infested timber may be removed before the beetles emerge to attack new trees. Logging schedules are dictated by the biology and habits of the beetle. In spite of these limitations, logging is more cost-effective than methods based on individual tree treatments and is the only method suitable for reducing beetle numbers in large infestations (e.g., larger than 10 to 20 ha, depending on the density of infested trees).

(2) Burning of the infested portion of the bole

i) Pile and burn (Fig. 10)

Infested trees are felled, leaving low stumps. The attacked portion is cut into lengths which can be handled, piled over stumps and burnt on site. The intensity of the burn must be such that the bark is completely charred on all logs. Fuel oil may be used to increase the intensity of the fire, particularly when the bark is green or moist.

This technique is effective anytime between attack and emergence of the young beetles. It is, however, time-consuming and restricted by fire hazard conditions, but it is useful for winter work on almost any terrain.

ii) Standing single trees (Fig. 11)

This procedure can be carried out with modified or standard initial fire-attack equipment; an all-terrain vehicle, with tank and pump-equipped

Fig. 10. Piling and burning operation. Fuel oil is sprayed on fire to increase intensity of burn.

Fig. 11. Burning single standing tree.

trailers, is required. A mixture of 90% fuel oil and 10% gasoline is sprayed on the bole, ignited, and additional mixture is sprayed on to maintain the fire for about three minutes. At this time, the edges of the bark flakes should have turned to a white ash. During cold weather, additional burning time will be necessary to attain temperatures under the bark sufficient to kill the beetles. Spot checks must be made to ensure that lethal temperatures are reached, and the burning time should be altered as required.

Modifications to the fire-attack equipment are unnecessary if the pump has a fuel oil-resistant impeller and appropriate (e.g., No. 4) nozzle. A delivery rate of 3.6 *l* (0.96 gal.) per minute at 69 kPa (10 psi) nozzle pressure allows treatment of a tree with 3.5 to 7 *l* of fuel. Trees should be burned to a height of 9 to 10 m.

The advantage of this technique is that about twice as many trees can be treated per day than with piling and burning. Terrain and stand density that restrict vehicle access and high fire hazard conditions limit the use of the technique.

(3) Herbicide (MSMA (monosodium methanearsonate)[1]) treatment of newly infested trees

The chemical is placed in a continuous shallow axe frill made around the tree near the base (within 0.3m of ground level) (Fig. 12). The frill should extend into the sapwood no deeper than 3 to 4 annual rings, i.e., just deep enough to hold the chemical. The chemical is dispensed into the frill with a squeeze bottle or other convenient dispenser at the rate of 0.4 ml per cm of circumference. The herbicide must be distributed along the entire length of the frill.

The major advantage of this technique is that all necessary equipment and materials can be easily transported in the woods. The major disadvantage is that trees must be treated within 24 days after attack has taken place. During this period, newly infested trees are difficult to find. The crowns are still green and the only evidence of attack is pitch tubes and boring dust on the bole.

[1] The use of pesticides in the forest requires that a permit be obtained from B.C. Ministry of Environment and that the operation be carried out under the supervision of the holder of a valid Pesticide Applicators Certificate. The mention of specific pesticides in this brochure indicates only that they are effective and available but does not indicate that they are presently registered for the purpose indicated.

Fig. 12. Frilled lodgepole pine with MSMA injected into the frill. Double filling ensures complete girdling of the stem.

Fig. 13. Wire screening "basket" attached to the lower bole of a baited and insecticide-treated pine to monitor flight.

Knowledge of the time of attack, which is necessary for proper timing of the treatment, can be obtained in two ways:

i) Establish several baited trap trees during late spring and examine them frequently for the first evidence of attack. Several trees are necessary since some of the trap trees may not be attacked.

ii) Place wire screen (5 to 7/cm mesh) baskets around the base of several baited, pesticide-treated trees (Fig. 13) to collect beetles killed

Fig. 14. Infested log pile sprayed with diesel oil and covered with plastic sheeting.

as they attempt to attack. The traps must be examined at 2 to 3 day intervals. A sudden increase in the number of beetles caught indicates a major flight has taken place.

(4) Insecticide treatment

Infested trees are felled, bucked when necessary, and the attacked portions are sprayed uniformly to drip point with a bark-penetrating solution of pesticide in fuel oil. About 0.5 ℓ of spray is required per m^2 of bark surface.

Chlorpyrifos[1], used as a spray containing 2% a.i. prepared from Dursban * in fuel oil, is effective for this purpose. The spray equipment can be of many types. The main requirements are that the parts be resistant to fuel oil and that the nozzle delivers a cone-shaped or fan-shaped spray. Fuel oil alone is also an effective treatment when sprayed to drip point on infested logs which are then tightly covered with plastic sheeting (Fig. 14).

Applications of insecticides in fuel oil can be made on standing trees (Fig. 15). The equipment should be capable of spraying up to 10 m high on the bole. Approximately 552 kPa (80 psi) pump pressure would be required. However, more spray hits non-target surfaces than when spraying felled trees.

Fig. 15. Spraying standing infested trees with bark penetrating insecticide to kill MPB broods under the bark.

These procedures are best carried out near the end of the life of the insect under the bark, i.e., in spring and early summer before the emergence and flight period. At this time, the foliage of trees attacked the previous year will have started to discolor and therefore groups of infested trees will be relatively easy to locate. Also, weathering and woodpecker work throughout the winter will have provided holes in the bark which aid penetration of pesticide. The major disadvantages are that equipment and materials have to be transported to the treatment site and the use of pesticides may be disagreeable. The use of protective clothing and appropriate face masks is required[1]. Pesticide label directions must be followed and appropriate permits must be obtained.

B) Preflight pheromone baiting of uninfested trees

Baiting of uninfested, untreated or pesticide-treated trap trees has two purposes: to trap and kill flying beetles attracted to them, and to serve as a nucleus for a spot infestation that can be treated later. The latter situation often occurs when there are more beetles than can be absorbed by the baited trees.

Baited trees should be the largest diameter pine available, preferably with a dbh of at least 25 cm. Trees must be baited prior to beetle flight. The commercially available bait consists of three message-bearing chemicals (semiochemicals): two beetle aggregating pheromones (*trans*-verbenol, produced by females and *exo*-brevicomin, produced by males) and a host-produced chemical, myrcene (Borden *et al.* 1983a, 1983b; Conn *et al.* 1983). The lures containing these three chemicals are attached to the tree (Fig. 16) preferably on the north side and above the understory canopy (PMG/Stratford Projects Ltd.[2] 1983).

Lethal trap trees are prepared by spraying the boles of baited trees to a height of at least 4 m with a nonpenetrating insecticide to kill beetles attracted to them. Boles are sprayed to the drip point. A preparation of 2% a.i. carbaryl in water prepared from Sevin S L [®] is effective[1].

Lethal trap trees will usually be attacked on bark

Fig. 16. Mountain pine beetle lure attached to a tree.

surfaces not treated or inadequately treated with insecticide and adjacent trees may also be attacked depending on beetle population size. Baited trees untreated with insecticide are also effective traps but generally trap fewer beetles than lethal trap trees; hence more adjacent trees may be attacked.

Infested trap trees and any adjacent attacked trees must be treated following attack to kill beetles and their broods.

The strategy of using semiochemicals for manipulating mountain pine beetle populations needs more development. Tree baiting is highly effective in inducing beetles to attack selected trees. This increases the effectiveness and the feasibility of direct control programs. Semiochemicals can be used for containment of medium-sized infestations (2-20 ha) in combination with sanitation logging, and reduction of dispersal of beetles from larger infestations. The general procedures of how to use semiochemicals to address these questions are contained in the Technical Bulletin by PMG/Stratford Ltd.[3] (1983).

[1] Current name of company is Pherotech Ltd.

Summary

The seasonal operations associated with control of incipient infestations of mountain pine beetle are summarized in the flowchart (Fig. 4). The underlying requirements of these operations are: (1) that control action must be initiated early in the infestation; (2) that all available techniques be used with coordinated, thorough application; and (3) that control action must be maintained until there is no evidence of infestation or until other management options are exercised.

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